

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

| | | | | |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|---------------------------------------------------------|------------------------------------------------------------------------|--|
| 1. AGENCY USE ONLY (Leave blank) | | 2. REPORT DATE 3-5-95 | 3. REPORT TYPE AND DATES COVERED Technical Report | |
| 4. TITLE AND SUBTITLE Synthesis and Characterization of a Series of Organoindium-Phosphides Including Molecular Structures of $[(Me_3CCH_2)_2InPET_2]_2$ and $[(Me_3CCH_2)_2InP(H)(C_6H_{11})]_3$ | | | 5. FUNDING NUMBERS Grant: N00014-90-J-1530 R&T Code: 4135002 | |
| 6. AUTHOR(S) O.T. Beachley, Jr., John D. Maloney, Michael A. Banks and Robin D. Rogers | | | | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Department of Chemistry State University of New York at Buffalo, NSM Complex Buffalo, NY 14260-3000 | | | 8. PERFORMING ORGANIZATION REPORT NUMBER Technical Report No. 41 | |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Office of Naval Research 800 N. Quincy Street Arlington, VA 22217-5000 | | | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER | |
| 11. SUPPLEMENTARY NOTES Accepted for publication - Organometallics | | | | |
| 12a. DISTRIBUTION/AVAILABILITY STATEMENT This document has been approved for public release and sale; its distribution is unlimited. Reproduction in whole or in part is permitted for any purpose of the United States government. | | | 12b. DISTRIBUTION CODE n/a | |
| 13. ABSTRACT (Maximum 200 words) A series of organoindium-phosphides including $(Me_3CCH_2)_2InPRR'$ ($R = R' = Et$, C_6H_{11} ; $R = C_6H_{11}$, $R' = H$; $R = Me$, $R' = Ph$) and $(Me_3SiCH_2)_2InP(Me)Ph$ have been prepared and characterized. The characterization data include partial elemental analyses (C, H), 1H and ^{31}P NMR and IR spectral studies, physical properties, cryoscopic molecular weight studies (with the exception of $(Me_3CCH_2)_2InP(C_6H_{11})_2$), and X-ray structural studies of $[(Me_3CCH_2)_2InPET_2]_2$ and $[(Me_3CCH_2)_2InP(H)(C_6H_{11})]_3$. The compound $(Me_3CCH_2)_2InPET_2$ is observed to be a dimer in benzene solution; $(Me_3CCH_2)_2InP(H)(C_6H_{11})$ exists as a dimer-trimer equilibrium mixture whereas $(Me_3CCH_2)_2InP(Me)(Ph)$ and $(Me_3SiCH_2)_2InP(Me)(Ph)$ are trimers. NMR studies are consistent with $(Me_3CCH_2)_2InP(C_6H_{11})_2$ being a dimer in benzene solution but the (continued on next page) | | | | |
| 14. SUBJECT TERMS Indium, indium phosphide precursors, structural studies | | | 15. NUMBER OF PAGES 31 | |
| | | | 16. PRICE CODE n/a | |
| 17. SECURITY CLASSIFICATION OF REPORT Unclassified | 18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified | 19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified | 20. LIMITATION OF ABSTRACT UL | |

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

DTIC QUALITY INSPECTED A

concentration was too low to confirm the conclusion by cryoscopic molecular weight studies. The compound $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$ crystallizes in the monoclinic space group C2/c with $a = 12.972(2)\text{\AA}$, $b = 15.539(5)\text{\AA}$, $c = 18.255(3)\text{\AA}$, $\beta = 99.84(1)^\circ$, $V = 3625.6\text{ \AA}^3$ and $Z = 4$ (dimeric molecules). The molecule contains a planar In_2P_2 core with In-P distances of $2.623(2)$ and $2.641(2)\text{\AA}$. The compound $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$ crystallizes in the triclinic space group $\text{P}\bar{1}$ with $a = 11.272(3)\text{\AA}$, $b = 13.992(5)\text{\AA}$, $c = 20.539(9)\text{\AA}$, $\alpha = 95.37(5)^\circ$, $\beta = 104.83(4)^\circ$, $\gamma = 109.14(4)^\circ$, $V = 2901.9\text{ \AA}^3$ and $Z = 2$ (trimeric molecules). The molecule has an In_3P_3 six-membered ring which is in the twist-boat conformation with In-P distances ranging from $2.613(3)$ to $2.659(2)\text{\AA}$.

| | |
|--------------------|-------------------------------------|
| Accession For | |
| NTIS CRA&I | <input checked="" type="checkbox"/> |
| DTIC TAB | <input type="checkbox"/> |
| Unannounced | <input type="checkbox"/> |
| Justification | |
| By | |
| Distribution / | |
| Availability Codes | |
| Dist | Avail and/or Special |
| A-1 | |

19950508 088

OFFICE OF NAVAL RESEARCH

Contract N-00014-90-J-1530

R&T Code 4135002

TECHNICAL REPORT NO. 41

Synthesis and Characterization of a Series of Organoindium-
Phosphides Including Molecular Structures of
 $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$ and $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$

by

O. T. Beachley, Jr., John D. Maloney, Michael A. Banks
and Robin D. Rogers

Prepared for Publication

in

Organometallics

State University of New York at Buffalo
Department of Chemistry
Buffalo, New York 14260-3000

3 May 1995

Reproduction in whole or in part is permitted for
any purpose of the United States Government

*This document has been approved for public release
and sale; its distribution is unlimited

**Synthesis and Characterization of a Series of Organoindium-
Phosphides Including Molecular Structures of
 $[(\text{Me}_3\text{CCH}_2)_2\text{InPET}_2]_2$ and $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$.**

O. T. Beachley, Jr.* , John D. Maloney and Michael A. Banks

Department of Chemistry

State University of New York at Buffalo

Buffalo, New York 14260

and

Robin D. Rogers*

Department of Chemistry, Northern Illinois University

DeKalb, IL 60115

Abstract – A series of organoindium-phosphides including $(\text{Me}_3\text{CCH}_2)_2\text{InPRR}'$ ($\text{R} = \text{R}' = \text{Et}$, C_6H_{11} ; $\text{R} = \text{C}_6\text{H}_{11}$, $\text{R}' = \text{H}$; $\text{R} = \text{Me}$, $\text{R}' = \text{Ph}$) and $(\text{Me}_3\text{SiCH}_2)_2\text{InP(Me)Ph}$ have been prepared and characterized. The characterization data include partial elemental analyses (C, H), ^1H and ^{31}P NMR and IR spectral studies, physical properties, cryoscopic molecular weight studies (with the exception of $(\text{Me}_3\text{CCH}_2)_2\text{InP(C}_6\text{H}_{11})_2$), and X-ray structural studies of $[(\text{Me}_3\text{CCH}_2)_2\text{InPET}_2]_2$ and $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$. The compound $(\text{Me}_3\text{CCH}_2)_2\text{InPET}_2$ is observed to be a dimer in benzene solution; $(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})$ exists as a dimer-trimer equilibrium mixture whereas

$(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})(\text{Ph})$ and $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})(\text{Ph})$ are trimers. NMR studies are consistent with $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ being a dimer in benzene solution but the concentration was too low to confirm the conclusion by cryoscopic molecular weight studies. The compound $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$ crystallizes in the monoclinic space group C2/c with $a = 12.972(2)\text{\AA}$, $b = 15.539(5)\text{\AA}$, $c = 18.255(3)\text{\AA}$, $\beta = 99.84(1)^\circ$, $V = 3625.6\text{\AA}^3$ and $Z = 4$ (dimeric molecules). The molecule contains a planar In_2P_2 core with In-P distances of 2.623(2) and 2.641(2) \AA . The compound $[(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{H})(\text{C}_6\text{H}_{11})]_3$ crystallizes in the triclinic space group $\text{P}\bar{1}$ with $a = 11.272(3)\text{\AA}$, $b = 13.992(5)\text{\AA}$, $c = 20.539(9)\text{\AA}$, $\alpha = 95.37(5)^\circ$, $\beta = 104.83(4)^\circ$, $\gamma = 109.14(4)^\circ$, $V = 2901.9\text{\AA}^3$ and $Z = 2$ (trimeric molecules). The molecule has an In_3P_3 six-membered ring which is in the twist-boat conformation with In-P distances ranging from 2.613(3) to 2.659(2) \AA .

Group 13-15 compounds of the type $R_2MER'_2$ have been used as single-source precursors¹⁻⁷ for ceramic and/or electronic materials and as amphoteric ligands for main-group elements compounds⁸⁻¹⁶ and for transition metals.^{17,18} In order for these types of compounds to be used most effectively for either of these purposes, it is necessary to first understand the advantages, disadvantages and limitations of the available preparative routes. Secondly, as these compounds are typically associated as dimers but occasionally trimers, the nature of their association and the thermodynamic factors which influence the different degrees of association and their stabilities in the different states of matter must be defined and fully understood. The monomer should be the more useful species for the preparation of materials by chemical vapor deposition because it should be more volatile. Furthermore, it is only the monomer which can be nominally classified as an amphoteric ligand. Since very few monomeric compounds^{19,20} of the type $R_2MER'_2$ have been observed, experimental observations of compounds which identify the existence of different degrees of association under different conditions or which identify equilibria between species of different degrees of association under a given set of conditions might be important for using these compounds for the above purposes.

A series of organoindium-phosphides, some of which are substituted with bulky ligands, $(Me_3CCH_2)_2InPEt_2$, $(Me_3CCH_2)_2InP(C_6H_{11})_2$, $(Me_3CCH_2)_2InP(H)(C_6H_{11})$, $(Me_3CCH_2)_2InP(Me)(Ph)$ and $(Me_3SiCH_2)_2InP(Me)(Ph)$ have been prepared in nearly quantitative yields by elimination reactions between the appropriate indium derivative (InR_3) and the phosphine. All reactions were carried out in heated benzene solutions such that the eliminated hydrocarbon (CMe_4 or $SiMe_4$) could be isolated, identified and weighed. The less bulky phosphines, $HPeEt_2$ and $H_2P(C_6H)_{11}$ were heated with $In(CH_2CMe_3)_3$ at

50 °C for 40 h each to achieve 96% yields of the corresponding products whereas HP(Me)(Ph) had to be heated with either $\text{In}(\text{CH}_2\text{CMe}_3)_3$ or $\text{In}(\text{CH}_2\text{SiMe}_3)_3$ at 80 °C for 4 days to achieve better than 95% yields of products. In contrast, when the most bulky phosphine, $\text{HP}(\text{C}_6\text{H}_{11})_2$ was allowed to react with $\text{In}(\text{CH}_2\text{CMe}_3)_3$, heating for 21 days at 60 °C was required to achieve a yield of higher than 90%. Heating for only 7 days provided a 43% yield whereas an additional 7 days increased the yield to only 78%. Thus, the elimination reaction between the organoindium compound and the phosphine appears to be the best reaction for preparing the indium phosphide products of highest purity for potential utilization as precursors for the chemical vapor deposition of electronic materials. This preparative method should not introduce any impurity which was not previously present in the indium or phosphorus precursors, the simplest reagents for the OMCVD process.

All compounds prepared in this investigation were as fully characterized as possible. X-ray structural studies of $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$ and $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$, cryoscopic molecular weight studies in benzene solution and ^{31}P and ^1H NMR spectral studies including some variable temperature studies were used to define the degrees of association of the compounds in the solid state and in solution, as appropriate. Physical properties, partial elemental analyses (C and H) and infrared spectra were used to define the identity and purity of the products.

Crystals of dineopentyl indium diethylphosphide are composed of discrete dimeric units of the formula $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$. The labelling of the atoms in the molecule are shown in Figure 1 and the interatomic bond distances and angles are listed in Tables 1 and 2. There are no abnormally close contacts in the unit cell. The In-P bond distances, 2.623(2) and 2.641(2) Å, are compared with the In-P distances in a variety of other dimers

and trimers in Table 3. The four-membered ring is planar as are all other $(R_2InPR'_2)_2$ compounds which have been structurally characterized (Table 3). The angles within the ring are smaller than the regular tetrahedral angle with observed values of $In-P(1)-In(a) = 97.51(9)^\circ$, $In-P(2)-In(a) = 96.66(8)^\circ$ and $P(1)-In-P(2) = 82.91(6)^\circ$.

Cryoscopic molecular weight studies and NMR spectral data indicate that $(Me_3CCH_2)_2InPEt_2$ exists as dimeric species in benzene solution as was observed in the solid state. The molecular weight and NMR (1H and ^{31}P) spectral data were independent of concentration, an observation which suggests the absence of species other than dimer. The 1H spectrum had lines for the methyl and methylene protons on phosphorus which were a triplet of doublets of doublets and a quartet of doublets of doublets, respectively. Thus, the lines for methyl group appeared as a pentet centered at 1.02 ppm with a coupling constant of 7.4 Hz and the methylene lines as an apparent quartet of triplets at 1.79 ppm ($^2J_{HCH} = 75$. Hz, $^2J_{PCH} = 2.0$ Hz). The methyl protons of the neopentyl groups was a singlet at 1.22 ppm whereas the methylene protons of the neopentyl groups was a triplet at 1.20 ppm ($^3J_{PGa-CH} = 2.1$ Hz). The triplet for the methylene protons of the neopentyl group has been observed previously for other related derivatives^{21,27} and arises from coupling between the protons and the two phosphorus atoms. Similar coupling may explain the multiplicities of the lines for the CH_2 and CH_3 protons of the ethyl groups bound to phosphorus. The $^{31}P\{^1H\}$ NMR spectrum in d^6 -benzene was a single line at -52.2 ppm.

The monocyclohexylphosphide derivative $(Me_3CCH_2)_2InP(H)(C_6H_{11})$ was isolated as a colorless crystalline solid which sublimed at 80 °C under high vacuum. Upon further heating, the compound underwent a glass transition at 120-125 °C and then melted over a

relatively broad range of 131-140 °C. Similar phase changes or glass transitions have been observed for other group 13-15 compounds²⁸⁻³¹ including some neopentyl derivatives.^{22,27} A glass transition, however, was not observed for $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$. These glass transitions have been suggested to be due to changes in the degree of association of the compound with heating.^{29,30} After $(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})$ melted, further heating caused the sample to turn yellow with bubbling at 150-170 °C. Then, the sample resolidified. These observations suggest the elimination of additional neopentane but further investigations of this reaction were not pursued.

Crystals of dineopentylindium monocyclohexylphosphide consisted of discrete trimeric units of the formula $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$, which are mutually separated by normal Van der Waals distances. The labelling of the atoms in the molecule are shown in Figure 2 whereas interatomic bond distances and angles are listed in Tables 4 and 5. The In_3P_3 ring for $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$ has a twist boat conformation. The internal ring angles are distorted from the regular tetrahedral angle and range from 128.90(9)-132.18(8)° for In-P-In and 92.85(8)-101.18(9)° for P-In-P, respectively. The ring conformation shown in Figure 2 reveals that the cyclohexyl substituents occupy the E,E,A (equatorial, equatorial, axial) positions on the In_3P_3 ring (twist boat). Similar observations of E,E,A positions for the cyclohexyl group in $[(\text{Me}_3\text{Si})_2\text{AlP(H)(C}_6\text{H}_{11})]_3$ ³² have been reported also. It has been suggested that the cyclohexyl groups in the E,E,A positions on the twist boat conformation minimize the steric interactions between the cyclohexyl groups and the substituents on the metal.³² Other angles including C-In-C (range from 125.9(5)-129.9(5)°) and In-C-C (range from 119.4(6)-125(1)°) are also distorted from the ideal tetrahedral value of 109.47°.

Comparisons between the In-P bond lengths in $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$ and indium phosphide dimers (Table 3) suggest that no correlation exists between In-P bond distances and the degree of association. The In-P bond distances for $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$ range from 2.613(3) to 2.659(2) Å. These In-P distances are comparable to the In-P bond distances in $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$ of 2.623(2) Å and 2.641(2) Å and all the other indium phosphide dimers. However, the In-P bond distances for $[(\text{Me}_3\text{CCH}_2)_2\text{InPPh}_2]_3$ ²¹ of 2.677(1) Å and 2.699(2) Å are longer.

Concentration dependent ^{31}P NMR spectra and molecular weight studies suggest that $(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})$ exists as a dimer-trimer equilibrium in benzene solution. Two sets of lines were observed in the $^{31}\text{P}\{^1\text{H}\}$ NMR spectrum at concentrations of 0.043 to 0.151 m. The $^{31}\text{P}\{^1\text{H}\}$ NMR spectrum of the 0.043 m solution exhibited two lines at -82.6 and -90.7 ppm assigned to phosphorus atoms of the *cis* and *trans* isomers of the dimer and eight lines from -112.3 to -114.4 ppm assigned to the phosphorus atoms in the multiple conformations of the ring and/or orientations of substituents on the trimer. The ratio of the peak heights for the dimer to trimer lines was 1.0:5.3, respectively. When the concentration was increased to 0.151 m, the spectrum revealed similar lines but the ratio of the peak heights for the dimer to trimer decreased (1.0:14.8) but the chemical shifts of the lines did not change. The $^{31}\text{P}\{^1\text{H}\}$ NMR spectrum of the 0.043 m solution was also investigated as a function of temperature, 20° to 60°. As the temperature increased, the ratio of peak heights of the dimer to trimer increased. This observation suggests the dimer to be more stable relative to the trimer at the higher temperature. Thus, enthalpies of solvation and entropies should be important factors. Since the ^1H NMR spectrum revealed multiple lines for both

the neopentyl and cyclohexyl groups which overlapped, assignments of the resonances to specific protons was not attempted.

The compounds $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ and $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ were prepared readily by elimination reactions between $\text{HP}(\text{Me})\text{Ph}$ and $\text{In}(\text{CH}_2\text{CMe}_3)_3$ or $\text{In}(\text{CH}_2\text{SiMe}_3)_3$, respectively. Dineopentylindium methylphenylphosphide was a colorless glassy solid which melted to a viscous oil at 30-52 °C whereas $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ was a colorless viscous oil at room temperature. Cryoscopic molecular weight studies suggest that both $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ and $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ are trimeric in benzene solution. The complexity of the ^1H and ^{31}P NMR spectra of $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ and $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ indicate a mixture of isomers of trimeric species in benzene. These isomers arise from the different orientations of the methyl and phenyl groups and/or different conformations of the ring.

The elimination reaction has also been utilized for the preparation of $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ from $\text{In}(\text{CH}_2\text{CMe}_3)_3$ and $\text{HP}(\text{C}_6\text{H}_{11})_2$ but heating in benzene at 60 °C for 21 days was required. The product was isolated in high yield (ca. 89%) as a colorless crystalline solid that was insoluble at room temperature in typical solvents including hydrocarbons, THF, Et_2O , and aromatic solvents. These solubility characteristics precluded cryoscopic molecular weight studies and extensive NMR studies. The crystalline solid had elemental analyses consistent with the empirical formula.

The limited experimental observations suggest that $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ exists as a dimer. The $^{31}\text{P}\{^1\text{H}\}$ NMR spectrum of $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ in d^8 -toluene at 70 °C revealed a singlet at -13.00 ppm. Since the chemical shift for $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ was only 2.43 ppm down field from the corresponding gallium analog³³

$[(\text{Me}_3\text{CCH}_2)_2\text{GaP}(\text{C}_6\text{H}_{11})_2]_2$, which was dimeric in benzene solution, $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ might be expected to be dimeric also. The weak Lewis basicity and large size of dicyclohexylphosphide would be expected to favor a low degree of association. It should be noted that $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ does not melt below 200 °C but decomposes at 225-229 °C. These observations suggest that $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ is not a simple monomer. It is noteworthy that $[\text{Me}_2\text{InP}(\text{t-Bu})_2]_2$ exists as a dimer in the solid state and it is also insoluble in Et_2O , hydrocarbons and aromatic solvents.²³

EXPERIMENTAL

All compounds described in this investigation were extremely sensitive to oxygen and moisture and were manipulated in a standard vacuum line or under a purified argon atmosphere. The compounds $\text{In}(\text{CH}_2\text{SiMe}_3)_3$ ³⁴ and $\text{In}(\text{CH}_2\text{CMe}_3)_3$ ³⁵ were prepared and purified by literature methods. Dicyclohexylphosphine was purchased from Alfa Products; $\text{HP}(\text{Me})\text{Ph}$ was purchased from Strem Chemicals, Inc., and HPe_2 and $\text{H}_2\text{P}(\text{C}_6\text{H}_{11})$ were generous gifts from the Eastman Kodak Company. All phosphines were purified by distillation prior to use. Solvents were dried by conventional procedures. Elemental analyses were performed by E+R Microanalytical Laboratory, Inc. Corona, NY or Schwarzkopf Microanalytical Laboratory, Woodside, New York. Infrared spectra of Nujol mulls between CsI plates were recorded by means of a Perkin-Elmer 683 spectrometer. The ^1H spectra was recorded at 300 MHz by using a Varian Gemini-300 spectrometer. Proton chemical shifts are reported in δ units (ppm) and are referenced to SiMe_4 at δ 0.00 ppm and C_6D_6 at δ 7.15 ppm. The ^{31}P NMR spectrum was recorded at 161.9 MHz on a Varian VXR-400 spectrometer. Proton-decoupled ^{31}P NMR spectra were referenced to 85%

H_3PO_4 at δ 0.00 ppm. All samples for NMR spectra were contained in sealed NMR tubes. Melting points were observed in sealed capillaries. Molecular weights were measured cryoscopically in benzene by using an instrument similar to that described by Shriver and Drezdson.³⁶

Synthesis of $(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2$. A tube with a Teflon valve was charged with 0.641 g (7.11 mmol) of HPEt_2 . A 100-mL Schlenk flask equipped with a 20 mm Solv-Seal joint was charged with 2.335 g (7.111 mmol) of $\text{In}(\text{CH}_2\text{CMe}_3)_3$ in the glove box. The Schlenk flask was capped, cooled to -196°C and evacuated. The HPEt_2 was vacuum distilled into the Schlenk flask along with 30 mL of benzene. The reaction mixture was warmed to ambient temperature, and then the Schlenk flask was immersed into a 50°C oil bath for 6 days. The volatile components were removed and fractionated through two -78°C traps into a -196°C trap. Neopentane (0.466 g, 6.46 mmol, 90.9% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$) was isolated in the -196°C trap and identified by ^1H NMR spectroscopy. The Schlenk flask was fitted with a medium frit equipped with a Schlenk receiving vessel. One extraction with 30 mL of benzene provided a soluble, colorless solid $(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2$ (2.080 g, 6.907 mmol, 97.13% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$). Crystallographic quality crystals were obtained from a saturated pentane solution maintained at -10°C . **$(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2$.** mp $105\text{--}106^\circ\text{C}$, sublimes at 70°C , 0.01 mm. ^1H NMR (C_6D_6 , δ): 1.02 (tdd, see Discussion, $^2J_{\text{HCH}} = 7.4\text{ Hz}$, 2.7 H, $-\text{CH}_3$), 1.20 (t, $^3J_{\text{PGaCH}} = 2.1\text{ Hz}$, 2.0 H, $\text{In}-\text{CH}_2-$), 1.22 (s, 7.0 H, $-\text{CMe}_3$), 1.79 (qdd, see Discussion, $^2J_{\text{HCH}} = 7.5\text{ Hz}$, $^2J_{\text{PCH}} = 2.0\text{ Hz}$, 1.7 H, $\text{P}-\text{CH}_2-$). $^{31}\text{P}\{^1\text{H}\}$ NMR (C_6D_6 , δ): -52.19 (s). Anal. Calcd.: C, 48.45; H, 9.24. Found: C, 48.44; H, 9.37. Cryoscopic molecular weight, formula weight 346.52 (obsd molality, obsd mol wt, association): 0.0805, 746, 2.15; 0.0658, 744, 2.15; 0.0529, 745, 2.15. IR (Nujol mull, cm^{-1}):

2725 (vw), 2698 (vw), 1412 (m), 1352 (vs), 1210 (sh), 1105 (m), 1092 (m), 1036 (s), 1020 (m), 1008 (m), 968 (m), 926 (w), 907 (w), 757 (m), 739 (m), 717 (m), 689 (vs), 680 (vs), 660 (m), 568 (m), 555 (sh), 448 (w), 258 (vw), 237 (w).

Synthesis of $(\text{Me}_3\text{CCH}_2)_2\text{InP(H)}(\text{C}_6\text{H}_{11})$. The compound $(\text{Me}_3\text{CCH}_2)_2\text{InP(H)}(\text{C}_6\text{H}_{11})$ was prepared from $\text{In}(\text{CH}_2\text{CMe}_3)_3$ (1.941 g, 5.912 mmol) and $\text{H}_2\text{PC}_6\text{H}_{11}$ (0.687 g, 5.91 mmol) in benzene by using the method previously described for $(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2$. After the reaction mixture was maintained at 50 °C for 40 h, neopentane CMe_4 (0.409 g, 5.67 mmol, 95.9% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$) was collected. Two extractions with 30 mL of benzene yielded a colorless solid $(\text{Me}_3\text{CCH}_2)_2\text{InP(H)}(\text{C}_6\text{H}_{11})$ (1.919 g, 5.156 mmol, 90.9% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$). Crystallographic quality crystals were obtained from a saturated benzene solution that was prepared by heating the same sample to 50 °C and then cooling the solution to ambient temperature. $(\text{Me}_3\text{CCH}_2)_2\text{InP(H)}(\text{C}_6\text{H}_{11})$. mp glass transition 120-125 °C, melts at 131-140 °C, bubbles at 150-170 °C. ^1H NMR (C_6D_6 , δ): 1.18 (m, $-\text{CH}_2-$), 1.23 (s, $-\text{CMe}_3$), 1.28 (s, $-\text{CMe}_3$), 1.41 (s, C_6H_{11}), 1.47 (s, C_6H_{11}), 1.51 (d, $^2J_{\text{HCH}} = 10.5$ Hz, C_6H_{11}), 1.67 (s, C_6H_{11}), 2.07 (d, $^2J_{\text{HCH}} = 10.5$ Hz, C_6H_{11}), 2.21 (m, C_6H_{11}), 2.48 (m, P-H), 3.32 (m, P-H). $^{31}\text{P}\{^1\text{H}\}$ NMR (0.043 m, C_6D_6 , δ): -82.62 (s, 2.9), -90.68 (s, 1.7), -106.2 (s, 0.5), -106.7 (s, 0.4), -112.3 (s, 1.0), -112.7 (s, 1.0), -112.9 (s, 1.6), -113.2 (s, 2.3), -113.3 (s, 5.5), -113.8 (s, 8.0), -114.2 (s, 2.8), -114.4 (s, 2.3). $^{31}\text{P}\{^1\text{H}\}$ NMR (0.043 m at 40 °C, C_6D_6 , δ): -82.95 (s, 5.4), -90.90 (s, 3.5), -112.3 (s, 1.0), -112.7 (s, 1.0), -112.9 (s, 1.8), -113.3 (s, 7.1), -113.8 (s, 7.0), -114.2 (s, 2.9), -114.4 (s, 2.4). $^{31}\text{P}\{^1\text{H}\}$ NMR (0.043 m at 60 °C, C_6D_6 , δ): -83.30 (s, 9.1), -91.17 (s, 6.8), -112.2 (s, 1.0), -112.6 (s, 1.2), -112.9 (s, 1.8), -113.3 (s, 10.9), -113.7 (s, 6.8), -114.0 (s, 2.6), -114.3 (s, 1.8). $^{31}\text{P}\{^1\text{H}\}$ NMR (0.151 m, C_6D_6 , δ): -82.3 (s, 1.7), -90.4 (s, 1.0), -106.2 (s, 0.4), -106.7 (s, 0.3), -112.3 (s, 1.1),

-112.8 (s, 1.4), -112.9 (s, 2.2), -113.2 (s, 7.9), -113.3 (s, 5.7), -114.0 (s, 13.4), -114.4 (s, 4.4), -114.5 (s, 3.8). Anal. Calcd.: C, 51.62; H, 9.21. Found: C, 51.77; H, 9.22. Cryoscopic molecular weight, formula weight 371.78 (obsd molality, obsd mol wt, association): 0.0754, 1041, 2.80; 0.0584, 1052, 2.83; 0.0441, 1029, 2.76. IR (Nujol mull, cm^{-1}): 2325 (m), 2303 (m), 2290 (m), 1354 (vs), 1292 (m), 1258 (m), 1230 (vs), 1190 (m), 1173 (m), 1105 (s), 1090 (s), 1068 (w), 1045 (w), 1008 (m), 995 (s), 928 (vw), 914 (w), 907 (w), 892 (m), 885 (m), 848 (m), 820 (m), 805 (m), 740 (m), 719 (m), 686 (s), 670 (s), 620 (w), 600 (w), 568 (s), 506 (vw), 445 (m), 375 (w), 343 (m), 290 (m).

Synthesis of $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$. The compound $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ was prepared from $\text{In}(\text{CH}_2\text{CMe}_3)_3$ (3.321 g, 10.118 mmol) and $\text{HP}(\text{Me})\text{Ph}$ (1.256 g, 10.118 mmol) in benzene by using the method previously described for $(\text{Me}_3\text{CCH}_2)_2\text{InPET}_2$. Heating at 80 °C for 4 days gave 0.714 g CMe_4 , 9.90 mmol, 97.8% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$. The crude product was extracted with 45 mL of anhydrous pentane to yield $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ as a colorless material (3.202 g, 8.421 mmol, 83.23% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$). **$(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$.** mp: 30-52 °C (169-172 °C dec.). Material was glass-like in appearance and melted to a thick oil over a broad range. ^1H NMR (C_6D_6 , δ): 0.95, 1.00, 1.01, 1.05, 1.08 (s, 18 H, $-\text{CMe}_3$); 1.20, 1.21, 1.23, 1.26 (4.1 H, $-\text{CH}_2-$); 1.72, 1.76 (m, 2.6 H, PMe). $^{31}\text{P}\{^1\text{H}\}$ NMR (C_6D_6 , δ): -97.6 (s, 11.4), -98.1 (s, 1.00), 98.5 (s, 2.19), -98.7 (s, 8.98), -98.9 (s, 5.07), -99.1 (s, 2.05). Anal. Calcd.: C, 53.69; H, 7.97. Found: C, 53.72; H, 8.26. Cryoscopic molecular weight, formula weight 380.26 (obsd molality, obsd mol wt, association): 0.0787, 1099, 2.89; 0.0657, 1065, 2.80. IR (Nujol mull cm^{-1}): 3078 (w), 3058 (w), 1955 (vw), 1938 (vw), 1795 (vw), 1582 (w), 1480 (s), 1431 (s), 1357 (s), 1308 (vw), 1295 (vw), 1270 (vw), 1265 (w), 1233 (m), 1210 (w), 1199 (vw), 1188 (vw), 1152 (vw),

1108 (w), 1095 (w), 1070 (vw), 1025 (w), 1010 (m), 998 (m), 960 (vw), 928 (vw), 908 (vw), 878 (s), 732 (vs), 689 (vs), 675 (m, sh), 665 (m, sh), 612 (vw), 568 (m), 478 (m), 448 (w), 404 (w), 378 (vw), 330 (vw), 310 (vw), 282 (vw).

Synthesis of $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$. The compound $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ was prepared from $\text{In}(\text{CH}_2\text{SiMe}_3)_3$ (0.820 g, 2.18 mmol) and $\text{HP}(\text{Me})\text{Ph}$ (0.271 g, 2.18 mmol) in benzene by using the method previously described for $(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2$. Heating at 80 °C for 4 days gave 0.181 g CMe_4 , 1.84 mmol, 84.4% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$. The product was extracted with 45 mL of anhydrous pentane to yield $(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$ as a viscous oil (0.892 g, 2.16 mmol, 99.3% yield based on $\text{In}(\text{CH}_2\text{SiMe}_3)_3$).

$(\text{Me}_3\text{SiCH}_2)_2\text{InP}(\text{Me})\text{Ph}$. ^1H NMR (C_6D_6 , δ): -0.01, 0.03, 0.06, 0.08, 0.10, 0.16, 0.17, 0.18, 0.20, 0.24, 0.26, 0.28, 0.29, 0.37, 0.38 (s, combined lines 22 H, $-\text{CH}_2\text{SiMe}_3$); 1.81, 1.82, 1.84, 1.87 (s, 3 H, $-\text{PMe}$). $^{31}\text{P}\{^1\text{H}\}$ NMR (C_6D_6 , δ): -69.6 (s, 1.6), -69.9 (s, 3.1), -70.5 (s, 3.0), -70.8 (s, 1.3), -92.2 (s, 7.9), -98.7 (s, 50.7), -99.2 (s, 96.3). Anal. Calcd.: C, 43.68; H, 7.35. Found: C, 43.49; H, 7.43. Cryoscopic molecular weight, formula weight 412.42 (obsd molality, obsd mol wt, association): 0.0702, 1196, 2.90; 0.0562, 1192, 2.89; 0.0438, 1233, 2.99. IR (Nujol mull cm^{-1}): 3072 (w), 3056 (w), 1562 (w), 1480 (m), 1431 (m), 1424 (m, sh), 1349 (w), 1330 (vw), 1308 (vw), 1275 (w, br), 1252 (m), 1240 (vs), 1152 (vw), 1068 (vw), 1022 (vw), 996 (vw), 955 (m, br), 878 (m), 848 (vs), 820 (vs), 745 (m), 731 (s), 718 (m), 688 (m), 678 (m), 605 (vw), 560 (w), 550 (w), 475 (w), 352 (vw), 345 (vw), 338 (vw), 325 (vw).

Synthesis of $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$. In the glove box, tared screw-cap vials were charged with 0.721 g (3.64 mmol) of $\text{HP}(\text{C}_6\text{H}_{11})_2$ and with 1.194 g (3.636 mmol) of $\text{In}(\text{CH}_2\text{CMe}_3)_3$. The contents of each vial was transferred quantitatively into a 100-mL Schlenk flask equipped with a 20-mm Solv-Seal joint by using 5 separate 3 mL washings of

benzene. The Schlenk flask was capped, cooled to $-196\text{ }^{\circ}\text{C}$, and evacuated. The reaction mixture was heated with a $60\text{ }^{\circ}\text{C}$ oil bath for 7 days. The volatile component were removed and fractionated through two $-78\text{ }^{\circ}\text{C}$ traps into a $-196\text{ }^{\circ}\text{C}$ trap. Neopentane (0.112 g, 1.56 mmol, 42.9% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$) was isolated in the $-196\text{ }^{\circ}\text{C}$ trap. The neopentane and benzene were vacuum distilled back into the original Schlenk reaction flask and heated at $60\text{ }^{\circ}\text{C}$ for another 7 days. Fractionation yielded 0.206 g CMe_4 , 3.42 mmol, 78.4% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$). Again, the neopentane and benzene were vacuum distilled into the original flask and heated at $60\text{ }^{\circ}\text{C}$. After another week (21 days total) fractionation yielded 0.247 g CMe_4 , 3.42 mmol, 94.1% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$. The product was washed with 20 mL of anhydrous pentane to leave $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$ as a colorless crystalline solid (1.466 g (3.227 mmol, 88.76% yield based on $\text{In}(\text{CH}_2\text{CMe}_3)_3$)). $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{C}_6\text{H}_{11})_2$. mp 225-229 $^{\circ}\text{C}$ dec. $^{31}\text{P}\{^1\text{H}\}$ NMR (70 $^{\circ}\text{C}$, $\text{C}_6\text{D}_5\text{CD}_3$, δ): -13.00 (s). Anal. Calcd.: C, 58.15; H, 9.76. Found: C, 58.41; H, 9.41. IR (Nujol mull, cm^{-1}): 2700 (vw), 1340 (m), 1334 (m), 1327 (m), 1296 (w), 1290 (m), 1257 (m), 1227 (s), 1208 (m), 1186 (m), 1172 (s), 1163 (m), 1094 (m), 1089 (sh), 1065 (w), 1042 (w), 1036 (vw), 1020 (w), 1009 (m), 995 (s), 922 (vw), 910 (w), 901 (w), 880 (m), 844 (s), 813 (vw), 780 (vw), 737 (s), 725 (m), 671 (vs), 640 (s), 507 (w), 448 (m), 430 (sh), 380 (w), 350 (w), 318 (vw), 288 (m). Solubility: trace solubility in aromatic solvents and insoluble in Et_2O , THF and hydrocarbons.

X-ray Data Collection, Structure Determination and Refinement for

$[(\text{Me}_3\text{CCH}_2)_2\text{InPET}_2]_2$. A transparent single crystal of $[(\text{Me}_3\text{CCH}_2)_2\text{InPET}_2]_2$ was mounted in a thin-walled glass capillary under Ar and transferred to the goniometer. The space group was determined to be either the centric C2/c or acentric Cc from the systematic

absences. The subsequent solution and successful refinement of the structure was carried out in the centric space group $C2/c$. A summary of data collection parameters is given in Table 6.

Least-squares refinement with isotropic thermal parameters led to $R = 0.066$. Disorder was obvious in the neopentyl group C(6)-C(10). The disorder resolved itself into two orientations of C(6), C(9), and C(10). C(7) and C(8) were common to both. Refinement of the occupancy factors gave C(6), C(9), C(10) at 55% and their primed counterparts at 45%. The two orientations were refined in alternate least-squares cycles. The hydrogen atoms were not included in the final refinement. Refinement of nonhydrogen atoms with anisotropic temperature factors led to the final values of $R = 0.045$ and $R = 0.076$. The final values of the positional parameters are given in Table 7.

X-ray Data Collection, Structure Determination and Refinement for

$[(Me_3CCH_2)_2InP(H)(C_6H_{11})]_2$. A transparent single crystal of $[(Me_3CCH_2)_2InP(H)(C_6H_{11})]_2$ was mounted in a thin-walled glass capillary under Ar and transferred to the goniometer. The space group was determined to be either the centric $P\bar{1}$ or acentric $P1$. The subsequent solution and successful refinement of the structure was carried out in the centric space group $P\bar{1}$. A summary of data collection parameters is given in Table 8.

High thermal motion was noted for almost all C atoms. The only resolvable disorder was two orientations for the C(31)-C(36) cyclohexyl group. C(34)-C(36) and C(34)'-C(36)' were refined with 50% occupancy in alternate least-squares cycles. Due to the thermal motion and disorder the hydrogen atoms were not included in the final refinement. Refinement of nonhydrogen atoms with anisotropic temperature factors led to the final

values of $R = 0.054$ and $R_w = 0.078$. The final values of the positional parameters are given in Table 9.

Acknowledgement. This work was supported in part by the Office of Naval Research (OTB) and by a generous grant from Eastman Kodak Company. We thank Dr. Henry J. Gysling for his work on the synthesis and characterization of $(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{Me})\text{Ph}$.

Supplementary Material. Listings of anisotropic thermal parameters and bond distances and angles (pages); a listing of observed and calculated structure factors for $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]$ and $[(\text{Me}_3\text{CCH}_2)_2\text{InP}(\text{H})(\text{C}_6\text{H}_{11})]_3$.

Table 1. Interatomic Distances (Å) for [(Me₃CCH₂)₂InPEt₂]₂.

| | | | |
|----------------------------------------|----------|------------|----------|
| (A) Indium-Phosphorus Distances | | | |
| In-P(1) | 2.623(2) | In-P(2) | 2.641(2) |
| (B) Indium-Carbon Distances | | | |
| In-C(1) | 2.211(8) | In-C(6) | 2.17(2) |
| In-C(6) ^a | 2.29(3) | | |
| (C) Phosphorus-Carbon Distances | | | |
| P(1)-C(11) | 1.869(9) | P(2)-C(13) | 1.835(8) |

^aThe neopentyl group C(6)-C(10) is disordered.

Table 2. Angles (deg) for [(Me₃CCH₂)₂InPEt₂]₂.**(A) Angles around the Indium Atom**

| | | | |
|---------------|----------|---------------|----------|
| P(1)-In-P(2) | 82.91(6) | P(1)-In-C(1) | 111.1(2) |
| P(1)-In-C(6) | 115.7(4) | P(1)-In-C(6)' | 101.2(7) |
| P(2)-In-C(1) | 100.5(2) | P(2)-In-C(6) | 124.6(4) |
| P(2)-In-C(6)' | 118.1(6) | C(1)-In-C(6) | 116.9(5) |
| C(1)-In-C(6)' | 132.2(7) | | |

(B) Angles around the Phosphorus Atoms

| | | | |
|-------------------|----------|-------------------|----------|
| In-P(1)-In(a) | 97.51(9) | In-P(2)-In(a) | 96.66(8) |
| In-P(1)-C(11) | 113.5(3) | In-P(2)-C(13) | 120.4(3) |
| In-P(1)-C(11a) | 113.5(3) | In-P(2)-C(13a) | 107.9(3) |
| C(11)-P(1)-C(11a) | 105.5(5) | C(13)-P(2)-C(13a) | 104.5(5) |

(C) Indium-Carbon-Carbon Angles

| | | | |
|--------------|----------|---------------|--------|
| In-C(1)-C(2) | 118.7(6) | In-C(6)-C(7) | 123(1) |
| | | In-C(6)'-C(7) | 119(1) |

(D) Phosphorus-Carbon-Carbon Angles

| | | | |
|------------------|----------|------------------|----------|
| P(1)-C(11)-C(12) | 112.1(7) | P(2)-C(13)-C(14) | 113.3(6) |
|------------------|----------|------------------|----------|

^aSymmetry code: -x, y, 1/2-z.

Table 3. Indium-Phosphorus Bond Distances for Compounds of the Type $[R_2InPR'_2]_n$.

| Compound | d InP(Å) | | Reference |
|--------------------------------------|----------|----------|-----------|
| $[(Me_3CCH_2)_2InPEt_2]_2$ | 2.623(2) | | this work |
| | 2.641(2) | | |
| $[(Me_3CCH_2)_2InP(H)(C_6H_{11})]_3$ | 2.613(3) | 2.637(3) | this work |
| | 2.625(3) | 2.645(3) | |
| | 2.644(3) | 2.659(2) | |
| $[(Me_3CCH_2)_2InPPh_2]_3$ | 2.677(1) | | 21 |
| | 2.699(2) | | |
| $[(Me_3SiCH_2)_2InPPh_2]_2$ | 2.664(2) | 2.659(2) | 22 |
| | 2.643(2) | 2.632(2) | |
| $[Me_2InP(t-Bu)_2]_2$ | 2.656(4) | | 23 |
| | 2.637(4) | | |
| $[Et_2InP(t-Bu)_2]_2$ | 2.635(2) | | 24 |
| $[(Me_3SiCH_2)_2InP(SiMe_3)_2]_2$ | 2.654(2) | | 13 |
| | 2.656(2) | | |
| $[(Me_3SiCH_2)_2InP(H)(t-Bu)]_2$ | 2.633(1) | | 25 |
| | 2.638(1) | | |
| $[(C_5Me_5)(Cl)InP(SiMe_3)_2]_2$ | 2.648(2) | | 26 |
| | 2.594(1) | | |

| Table 4. Interatomic Distances (Å) for [(Me ₃ CCH ₂) ₂ InP(H)(C ₆ H ₁₁)] ₃ . | | | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|----------|-------------|----------|
| (A) Indium-Phosphorus Distances | | | |
| In(1)-P(1) | 2.644(3) | In(1)-P(3) | 2.613(3) |
| In(2)-P(2) | 2.645(3) | In(2)-P(1) | 2.637(3) |
| In(3)-P(3) | 2.659(2) | In(3)-P(2) | 2.625(3) |
| (B) Indium-Carbon Distances | | | |
| In(1)-C(1) | 2.195(8) | In(1)-C(6) | 2.22(1) |
| In(2)-C(11) | 2.20(1) | In(2)-C(16) | 2.19(2) |
| In(3)-C(21) | 2.188(9) | In(3)-C(26) | 2.16(1) |
| (C) Phosphorus-Carbon Distances | | | |
| P(1)-C(31) | 1.83(2) | P(2)-C(37) | 1.88(1) |
| P(3)-C(43) | 1.871(7) | | |

Table 5. Angles (deg) for $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$.**(A) Angles around the Indium Atoms**

| | | | |
|------------------|-----------|-------------------|----------|
| P(1)-In(1)-P(3) | 101.18(9) | P(1)-In(1)-C(1) | 98.1(3) |
| P(3)-In(1)-C(1) | 106.5(3) | P(1)-In(1)-C(6) | 104.4(3) |
| P(3)-In(1)-C(6) | 113.3(3) | C(1)-In(1)-C(6) | 128.6(5) |
| P(1)-In(2)-P(2) | 92.85(8) | P(1)-In(2)-C(11) | 105.5(3) |
| P(2)-In(2)-C(11) | 104.5(3) | P(1)-In(2)-C(16) | 118.3(4) |
| P(2)-In(2)-C(16) | 103.5(5) | C(11)-In(2)-C(16) | 125.9(5) |
| P(2)-In(3)-P(3) | 93.69(8) | P(2)-In(3)-C(21) | 98.4(3) |
| P(3)-In(3)-C(21) | 108.0(3) | P(2)-In(3)-C(26) | 113.9(3) |
| P(3)-In(3)-C(26) | 107.0(3) | C(21)-In(3)-C(26) | 129.9(5) |

(B) Angles around the Phosphorus Atoms

| | | | |
|------------------|-----------|------------------|----------|
| In(1)-P(1)-In(2) | 130.1(1) | In(2)-P(1)-C(31) | 107.2(5) |
| In(2)-P(2)-In(3) | 132.18(8) | In(1)-P(1)-C(31) | 107.6(6) |
| In(2)-P(2)-C(37) | 112.1(4) | In(3)-P(2)-C(37) | 107.0(4) |
| In(1)-P(3)-In(3) | 128.90(9) | In(1)-P(3)-C(43) | 105.8(3) |
| In(3)-P(3)-C(43) | 115.1(3) | | |

(C) Indium-Carbon-Carbon Angles

| | | | |
|-------------------|----------|-------------------|----------|
| In(1)-C(1)-C(2) | 120.4(6) | In(1)-C(6)-C(7) | 120.5(8) |
| In(2)-C(11)-C(12) | 119.7(7) | In(2)-C(16)-C(17) | 125(1) |
| In(3)-C(21)-C(22) | 121.3(6) | In(3)-C(26)-C(27) | 119.4(6) |

(D) Phosphorus-Carbon-Carbon Angles

| | | | |
|-------------------|----------|------------------|----------|
| P(1)-C(31)-C(32) | 114(1) | P(1)-C(31)-C(36) | 122(1) |
| P(1)-C(31)-C(36)' | 117(1) | P(2)-C(37)-C(38) | 112.4(8) |
| P(2)-C(37)-C(42) | 113(1) | P(3)-C(43)-C(44) | 110.6(6) |
| P(3)-C(43)-C(48) | 111.6(6) | | |

Table 6. Crystal Data and Summary of Intensity Data Collection and Structure Refinement of $[(\text{Me}_3\text{CCH}_2)_2\text{InPEt}_2]_2$.

| | |
|-----------------------------------------------------------------|---------------------------------------------------|
| molecular formula | $\text{C}_{28}\text{H}_{64}\text{In}_2\text{P}_2$ |
| color/shape | colorless/parallelepiped |
| mol wt | 684.34 |
| space group | C2/c |
| temp., °C (K) | 22 (295) |
| cell constants ^a | |
| a, Å | 12.972(2) |
| b, Å | 15.539(5) |
| c, Å | 18.255(3) |
| β , deg | 99.84(1) |
| V, Å ³ | 3625.6 |
| Z | 4 |
| D_{calc} , g cm ⁻³ | 1.25 |
| μ_{calc} , cm ⁻¹ | 13.6 |
| diffractometer/scan | Enraf-Nonius CAD-4/ ω -2 θ |
| range of relative transm factors, % | 89/100 |
| radiation, graphite monochromator (λ , Å) | MoK α ($\lambda = 0.71073$) |
| max cryst dims, mm | 0.20 × 0.30 × 0.35 |
| scan width | 0.80 + 0.35tan θ |
| std reflns | 600; 080; 0, 0, 14 |
| stds measd | ±2% |
| no. of reflns measd | 3454 |
| 2 θ range, deg | 2 ≤ 2 θ ≤ 50 |
| range of h, k, l | +15, +18, ±21 (h+k = 2n only) |
| no. of reflns observed [$F_o \geq 5\sigma(F_o)$] ^b | 2261 |
| computer programs ^c | SHELX ³⁷ |
| structure solution | SHELXS ³⁸ |
| no. of params varied | 175 |
| weights | $[\sigma(F_o)^2 + 0.002 F_o^2]^{-1}$ |
| GOF | 1.10 |
| $R = \Sigma F_o - F_c / \Sigma F_o $ | 0.045 |
| R_w | 0.076 |
| largest feature in final diff map, eÅ ⁻³ | 0.6 |

^aLeast-squares refinement of $((\sin\theta)/\lambda)^2$ values for 25 reflections $\theta > 19^\circ$.

^bCorrections: Lorentz-polarization and absorption (empirical, ψ scan).

^cNeutral scattering factors and anomalous dispersion corrections from ref 39.

Table 7. Final Fractional Coordinates for [(Me₃CCH₂)₂InPEt₂]₂.

| Atom | x/a | y/b | z/c | B(eqv) ^a |
|--------------------|------------|------------|------------|---------------------|
| In | 0.15096(4) | 0.87403(3) | 0.24587(3) | 2.47 |
| P(1) | 0.0000 | 0.7627(2) | 0.2500 | 2.65 |
| P(2) | 0.0000 | 0.9870(2) | 0.2500 | 2.25 |
| C(1) | 0.2453(7) | 0.8929(6) | 0.3576(5) | 3.66 |
| C(2) | 0.3422(6) | 0.8353(5) | 0.3815(4) | 2.68 |
| C(3) | 0.393(1) | 0.8615(9) | 0.4616(7) | 6.01 |
| C(4) | 0.4219(8) | 0.8468(8) | 0.3304(6) | 4.78 |
| C(5) | 0.3114(9) | 0.7398(6) | 0.3801(7) | 5.26 |
| C(6) | 0.236(1) | 0.860(1) | 0.1540(8) | 3.33 |
| C(6) ^{'b} | 0.196(2) | 0.843(2) | 0.133(1) | 5.24 |
| C(7) | 0.2110(8) | 0.9139(7) | 0.0823(5) | 4.35 |
| C(8) | 0.2780(9) | 0.8895(7) | 0.0234(6) | 5.09 |
| C(9) | 0.093(1) | 0.889(2) | 0.050(1) | 5.21 |
| C(10) | 0.208(2) | 1.004(1) | 0.091(1) | 6.26 |
| C(9)' | 0.125(2) | 0.956(2) | 0.048(1) | 7.72 |
| C(10)' | 0.293(2) | 0.988(2) | 0.136(1) | 7.15 |
| C(11) | 0.0242(7) | 0.6899(5) | 0.3327(5) | 3.59 |
| C(12) | -0.070(1) | 0.6320(6) | 0.3376(8) | 5.40 |
| C(13) | -0.0419(6) | 1.0592(5) | 0.1710(4) | 3.10 |
| C(14) | -0.1284(9) | 1.1242(6) | 0.1846(6) | 4.56 |

$$^a\text{B(eqv)} = 4/3[a^2\beta_{11} + b^2\beta_{22} + c^2\beta_{33} + ab(\cos\gamma)\beta_{12} + ac(\cos\beta)\beta_{13} + bc(\cos\alpha)\beta_{23}]$$

^bPrimed and unprimed atoms of like numbers are disordered. C(6), C(9), and C(10) are present at 55% occupancy, while their primed counterparts have 45% occupancy.

Table 8. Crystal Data and Summary of Intensity Data Collection and Structure Refinement of $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$.

| | |
|-----------------------------------------------------------------|---------------------------------------------------|
| molecular formula | $\text{C}_{48}\text{H}_{69}\text{In}_3\text{P}_3$ |
| color/shape | colorless/parallelepiped |
| mol wt | 1116.7 |
| space group | $\text{P}\bar{1}$ |
| temp., °C (K) | 20 (293) |
| cell constants ^a | |
| a, Å | 11.272(3) |
| b, Å | 13.992(5) |
| c, Å | 20.539(9) |
| α , deg | 95.37(5) |
| β , deg | 104.83(4) |
| γ , deg | 109.14(4) |
| V, Å ³ | 2901.9 |
| Z | 2 |
| D _{calc} , g cm ⁻³ | 1.28 |
| μ_{calc} , cm ⁻¹ | 12.87 |
| diffractometer/scan | Enraf-Nonius CAD-4/ ω -2 θ |
| range of relative transm factors, % | 85/100 |
| radiation, graphite monochromator (λ , Å) | MoK α ($\lambda = 0.71073$) |
| max cryst dimens, mm | 0.15 × 0.30 × 0.35 |
| scan width | 0.80 + 0.35tan θ |
| std reflns | 400; 030; 006 |
| decay of stds | ±3% |
| no. of reflns measd | 10,246 |
| 2 θ range, deg | 2 ≤ 2 θ ≤ 50 |
| range of h, k, l | +9, +12, ±17 |
| no. of reflns observed [$F_o \geq 5\sigma(F_o)$] ^b | 6051 |
| computer programs ^c | SHELX ³⁷ |
| structure solution | SHELXS ³⁸ |
| no. of params varied | 523 |
| weights | $[\sigma(F_o)^2 + 0.008 F_o^2]^{-1}$ |
| GOF | 0.40 |
| $R = \Sigma F_o - F_c / \Sigma F_o $ | 0.054 |
| R_w | 0.078 |
| largest feature in final diff map, eÅ ⁻³ | 1.2 near In(2) |

^aLeast-squares refinement of $((\sin\theta)/\lambda)^2$ values for 25 reflections $\theta > 20^\circ$.
^bCorrections: Lorentz-polarization and absorption (empirical, ψ scan).
^cNeutral scattering factors and anomalous dispersion corrections from ref 39.

**Table 9. Final Fractional Coordinates for
[(CH₃CH₂)₂InP(H)(C₆H₁₁)₃·**

| Atom | x/a | y/b | z/c | B(eqv) ^a |
|-------|-------------|------------|------------|---------------------|
| In(1) | 0.11661(6) | 0.51323(4) | 0.24386(3) | 2.77 |
| In(2) | 0.15441(6) | 0.83677(5) | 0.17487(3) | 3.27 |
| In(3) | -0.01876(6) | 0.74770(4) | 0.36161(3) | 3.21 |
| P(1) | 0.1225(2) | 0.6398(2) | 0.1559(1) | 3.40 |
| P(2) | 0.1579(2) | 0.8441(2) | 0.3045(1) | 3.39 |
| P(3) | -0.0307(2) | 0.5618(2) | 0.3106(1) | 3.02 |
| C(1) | -0.010(1) | 0.3687(7) | 0.1708(5) | 3.93 |
| C(2) | 0.0029(9) | 0.2664(7) | 0.1849(5) | 3.54 |
| C(3) | 0.138(1) | 0.269(1) | 0.1906(7) | 6.03 |
| C(4) | -0.037(1) | 0.2435(9) | 0.2503(6) | 5.98 |
| C(5) | -0.103(1) | 0.1781(9) | 0.1218(7) | 5.75 |
| C(6) | 0.326(1) | 0.5599(9) | 0.3072(5) | 4.55 |
| C(7) | 0.3606(9) | 0.5631(7) | 0.3839(5) | 3.56 |
| C(8) | 0.329(1) | 0.648(1) | 0.4187(7) | 7.11 |
| C(9) | 0.511(1) | 0.583(1) | 0.4120(7) | 5.82 |
| C(10) | 0.282(2) | 0.463(1) | 0.4006(8) | 7.60 |
| C(11) | 0.3602(9) | 0.9202(8) | 0.1804(6) | 4.32 |
| C(12) | 0.392(1) | 1.0013(8) | 0.1354(6) | 4.56 |
| C(13) | 0.332(2) | 0.951(1) | 0.0582(7) | 6.58 |
| C(14) | 0.341(1) | 1.0861(9) | 0.1515(8) | 6.19 |
| C(15) | 0.545(1) | 1.049(1) | 0.156(1) | 8.61 |
| C(16) | -0.014(1) | 0.880(1) | 0.1282(8) | 7.44 |
| C(17) | -0.137(1) | 0.8091(9) | 0.0746(6) | 4.80 |
| C(18) | -0.240(1) | 0.858(1) | 0.0584(9) | 8.11 |
| C(19) | -0.117(2) | 0.750(2) | 0.0157(8) | 8.78 |
| C(20) | -0.200(1) | 0.720(1) | 0.112(1) | 8.67 |
| C(21) | 0.108(1) | 0.7916(7) | 0.4684(5) | 4.08 |

Table 9 (continued)

| | | | | |
|--------------------|------------|-----------|-----------|------|
| C(22) | 0.059(1) | 0.7421(7) | 0.5257(5) | 4.35 |
| C(23) | -0.051(1) | 0.775(1) | 0.5379(7) | 6.94 |
| C(24) | 0.019(2) | 0.6281(9) | 0.5103(7) | 7.10 |
| C(25) | 0.180(2) | 0.784(1) | 0.5945(6) | 6.61 |
| C(26) | -0.211(1) | 0.7545(7) | 0.3177(6) | 4.57 |
| C(27) | -0.232(1) | 0.8600(8) | 0.3306(6) | 4.87 |
| C(28) | -0.204(2) | 0.897(1) | 0.4052(8) | 8.20 |
| C(29) | -0.147(2) | 0.937(1) | 0.299(1) | 9.11 |
| C(30) | -0.381(2) | 0.837(1) | 0.292(1) | 9.50 |
| C(31) | 0.234(2) | 0.624(1) | 0.1080(6) | 8.11 |
| C(32) | 0.210(1) | 0.657(1) | 0.0396(6) | 7.38 |
| C(33) | 0.264(2) | 0.596(2) | -0.010(1) | 6.18 |
| C(34) | 0.395(3) | 0.626(3) | 0.027(2) | 8.22 |
| C(35) | 0.375(2) | 0.534(2) | 0.0716(9) | 4.46 |
| C(36) | 0.272(3) | 0.535(2) | 0.107(1) | 5.81 |
| C(33) ^b | 0.332(3) | 0.668(2) | 0.007(2) | 9.60 |
| C(34)' | 0.360(3) | 0.560(2) | 0.016(2) | 7.76 |
| C(35)' | 0.420(2) | 0.580(2) | 0.096(1) | 6.48 |
| C(36)' | 0.344(2) | 0.621(2) | 0.1433(9) | 5.77 |
| C(37) | 0.248(1) | 0.9778(8) | 0.3571(6) | 5.01 |
| C(38) | 0.224(1) | 1.0568(8) | 0.3191(7) | 5.32 |
| C(39) | 0.300(2) | 1.167(1) | 0.3615(8) | 6.58 |
| C(40) | 0.435(2) | 1.188(1) | 0.3982(9) | 9.92 |
| C(41) | 0.450(1) | 1.108(1) | 0.4444(7) | 6.79 |
| C(42) | 0.389(1) | 0.997(1) | 0.3940(8) | 7.59 |
| C(43) | -0.2012(8) | 0.4643(6) | 0.2694(5) | 3.29 |
| C(44) | -0.263(1) | 0.4868(7) | 0.2018(5) | 3.94 |

Table 9 (continued)

| | | | | |
|-------|-----------|-----------|-----------|------|
| C(45) | -0.400(1) | 0.4012(9) | 0.1661(6) | 4.86 |
| C(46) | -0.489(1) | 0.397(1) | 0.2118(8) | 6.44 |
| C(47) | -0.427(1) | 0.3745(9) | 0.2797(8) | 5.81 |
| C(48) | -0.287(1) | 0.4570(7) | 0.3175(5) | 4.23 |

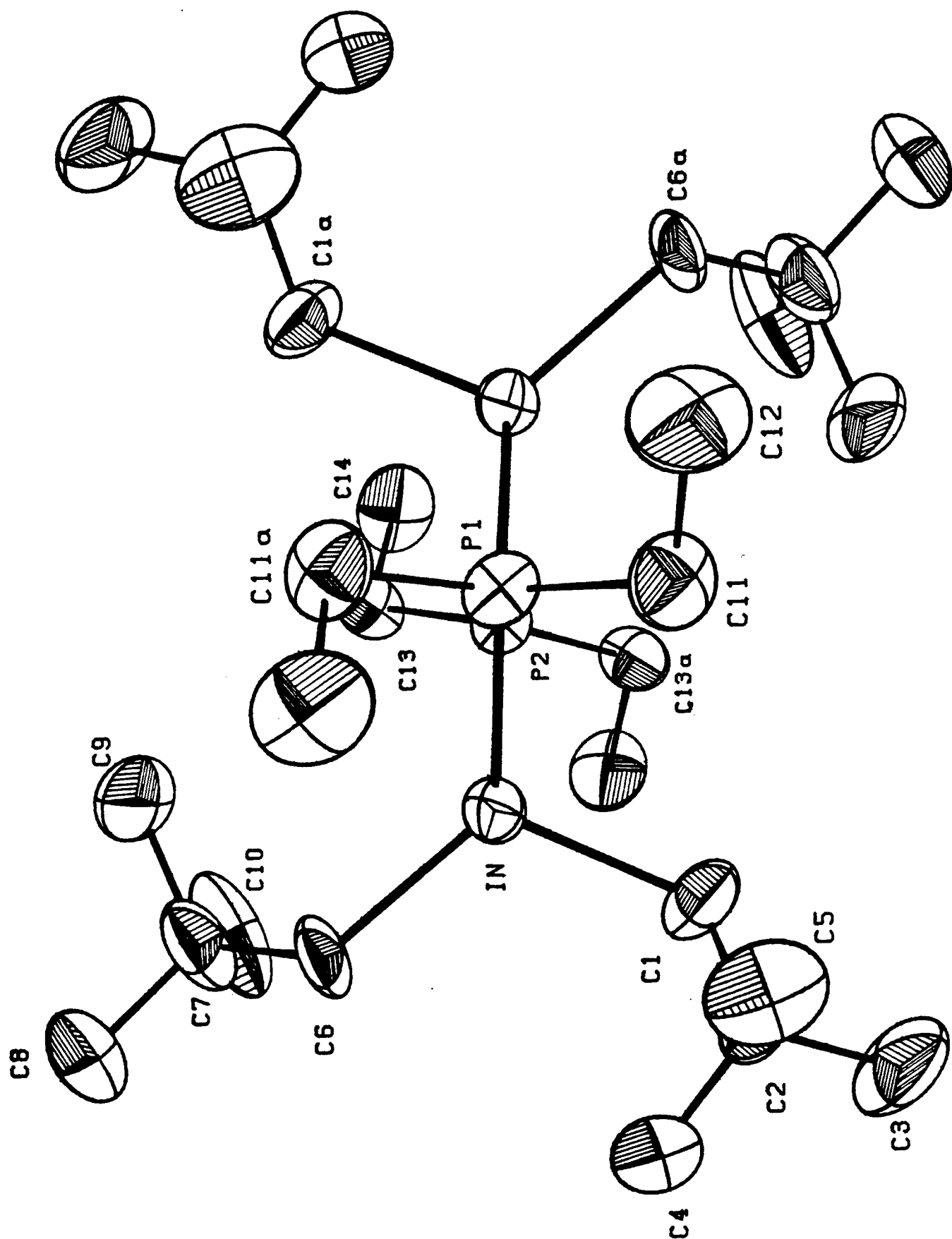
$$^aB(\text{eqv}) = 4/3[a^2\beta_{11} + b^2\beta_{22} + c^2\beta_{33} + ab(\cos\gamma)\beta_{12} + ac(\cos\beta)\beta_{13} + bc(\cos\alpha)\beta_{23}]$$

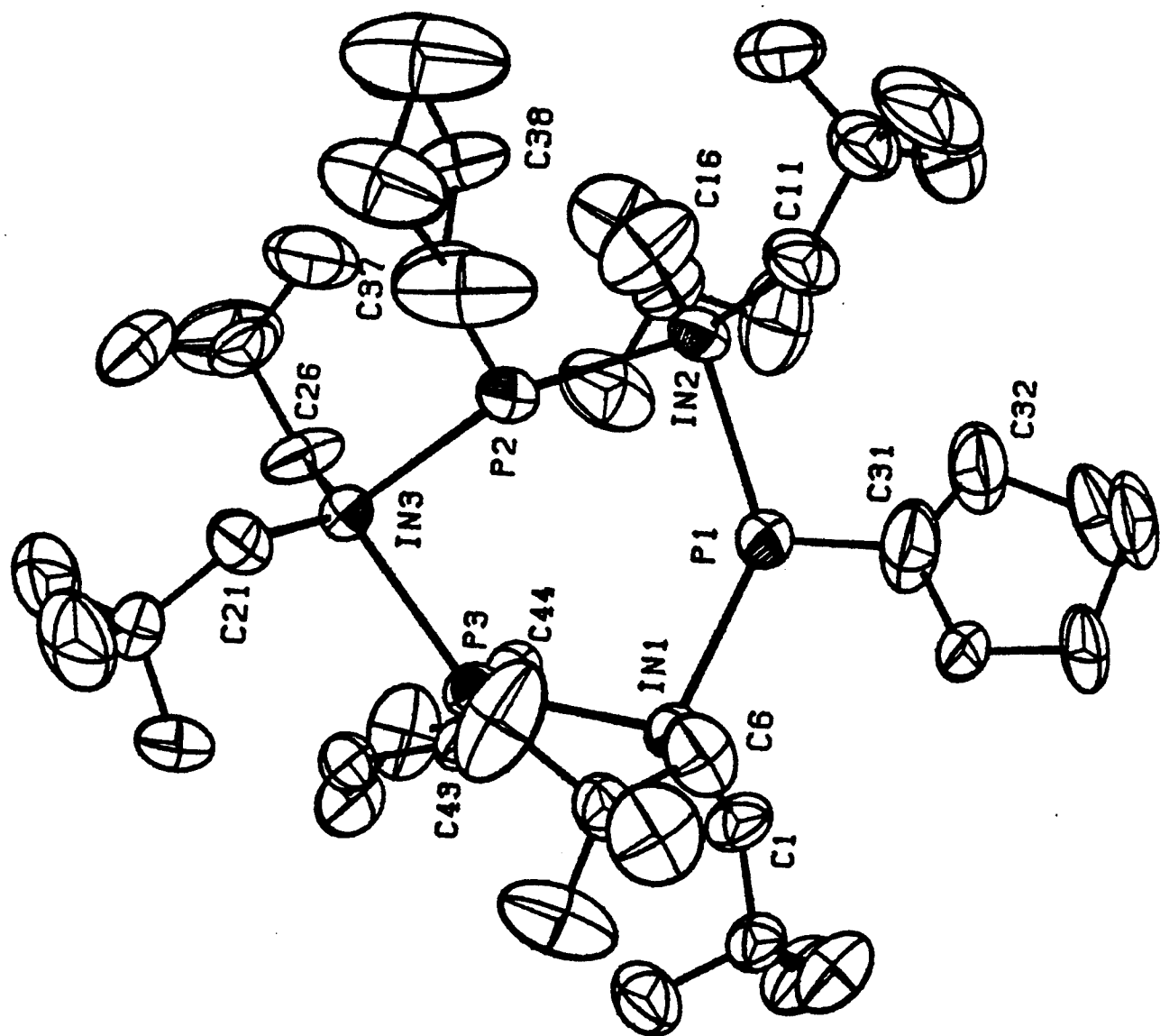
^bPrimed atoms are disordered with 50% occupancy each.

CAPTIONS FOR FIGURES

Figure 1. Labelling of atoms in $[(\text{Me}_3\text{CCH}_2)_2\text{InPET}_2]_2$ (ORTEP diagram; 50% ellipsoids).

Figure 2. Labelling of atoms in $[(\text{Me}_3\text{CCH}_2)_2\text{InP(H)(C}_6\text{H}_{11})]_3$ (ORTEP diagram; 50% ellipsoids).





REFERENCES

1. Cowley, A. H.; Benac, B. L.; Ekerdt, J. G.; Jones, R. A.; Kidd, K. B.; Lee, J. Y.; Miller, J. E. *J. Am. Chem. Soc.* **1988**, *110*, 6248.
2. Andrews, D. A.; Davies, G. J.; Bradley, D. C.; Faktor, M. M.; Frigo, D. M.; White, E. A. D. *Semicond. Sci. Technol.* **1988**, *3*, 1053.
3. Hwang, J.-W.; Hanson, S. A.; Britton, D.; Evans, J. F.; Jensen, K. F.; Gladfelter, W. L. *Chem. Mater.* **1990**, *2*, 342.
4. Miller, J. E.; Kidd, K. B.; Cowley, A. H.; Jones, R. A.; Ekerdt, J. G.; Gysling, H. J.; Weinberg, A. A.; Blanton, T. N. *Chem. Mater.* **1990**, *2*, 589.
5. Cowley, A. H.; Harris, P. R.; Jones, R. A.; Nunn, C. M. *Organometallics* **1991**, *10*, 652.
6. Miller, J. E.; Ekerdt, J. G. *Chem. Mater.* **1992**, *4*, 7.
7. Miller, J. E.; Mardones, M. A.; Nail, J. W.; Cowley, A. H.; Jones, R. A.; Ekerdt, J. G. *Chem. Mater.* **1992**, *4*, 447.
8. Wells, R. L.; Holley, W. K.; Shafieezad, S.; McPhail, A. T.; Pitt, C. G. *Phosphorus, Sulfur, Silicon Relat. Elem.* **1989**, *41*, 15.
9. Holley, W. K.; Wells, R. L.; Shafieezad, S.; McPhail, A. T.; Pitt, G. G. *J. Organomet. Chem.* **1990**, *381*, 15.
10. Wells, R. L.; Pasterczyk, J. W.; McPhail, A. T.; Johansen, J. D.; Alvanipour, A. J. *J. Organomet. Chem.* **1991**, *407*, 17.
11. Holley, W. K.; Pasterczyk, J. W.; Pitt, C. G.; Wells, R. L. *Heteroatom Chem.* **1990**, *1*, 475.
12. Wells, R. L.; Jones, L. J.; McPhail, A. T.; Alvanipour, A. *Organometallics* **1991**, *10*, 2345.

13. Wells, R. L.; McPhail, A. T.; Self, M. F. *Organometallics* **1991**, *11*, 221.
14. Wells, R. L.; McPhail, A. T.; Pasterzyk, J. W.; Alvanipour, A. *Organometallics* **1992**, *11*, 226.
15. Wells, R. L.; Aubuchon, S. R.; Self, M. F.; Jasinski, J. P.; Woudenberg, R. C.; Butcher, R. J. *Organometallics* **1992**, *11*, 3370.
16. Wells, R. L.; McPhail, A. T.; Self, M. F. *Organometallics* **1993**, *12*, 3363.
17. Tessier-Youngs, C.; Bueno, C.; Beachley, O. T., Jr.; Churchill, M. R. *Inorg. Chem.* **1983**, *22*, 1054.
18. Tessier-Youngs, C.; Youngs, W. J.; Beachley, O. T., Jr.; Churchill, M. R. *Organometallics* **1983**, *2*, 1128.
19. Byrne, E. K.; Parkanyi, L.; Theopold, K. H. *Science* **1988**, *241*, 332.
20. Higa, K. T.; George, C. *Organometallics* **1990**, *9*, 275.
21. Banks, M. A.; Beachley, O. T., Jr.; Buttrey, L. A.; Churchill, M. R.; Fettingner, J. C. *Organometallics* **1991**, *10*, 1901.
22. Beachley, O. T., Jr.; Kopasz, J. P.; Zhang, H.; Hunter, W. E.; Atwood, J. L. *J. Organomet. Chem.* **1987**, *325*, 69.
23. Aitchison, K. A.; Baker-Dirks, J. D. J.; Bradley, D. C.; Faktor, M. M.; Frigo, D. M.; Hursthouse, M. B.; Hussain, B.; Short, R. L. *J. Organomet. Chem.* **1989**, *336*, 11.
24. Alcock, N. W.; Degnan, I. E.; Wallbridge, M. G. H.; Powell, H. R.; McPartlin, M.; Sheldrick, G. M. *J. Organomet. Chem.* **1989**, *361*, C33.
25. Dembowski, U.; Noltemeyer, M.; Rockensüss, W.; Stuke, M.; Roesky, H. W. *Chem. Ber.* **1990**, *123*, 2335.
26. Theopold, K. H.; Douglas, T. *Inorg. Chem.* **1991**, *30*, 594.

27. Beachley, O. T., Jr.; Banks, M. A.; Churchill, M. R.; Feighery, W. G.; Fettingner, J. C. *Organometallics* **1991**, *10*, 3036.
28. Coates, G. E.; Graham, J. J. *Chem. Soc.* **1963**, 233.
29. Beachley, O. T., Jr.; Coates, G. E. *J. Chem. Soc.* **1965**, 3241.
30. Beachley, O. T., Jr.; Coates, G. E.; Kohnstam, G. J. *Chem. Soc.* **1965**, 3248.
31. Beachley, O. T., Jr.; Tessier-Youngs, C. *Organometallics* **1983**, *2*, 796.
32. Janik, J. F.; Duesler, E. N.; McNamara, W. F.; Westerhausen, M.; Paine, R. T. *Organometallics* **1989**, *8*, 506.
33. Maloney, J. D., Ph.D. Thesis, State University of New York at Buffalo, Buffalo, NY 1991.
34. Beachley, O. T., Jr.; Rusinko, R. N. *Inorg. Chem.* **1979**, *18*, 1966.
35. Beachley, O. T., Jr.; Spiegel, E. F.; Kopasz, J. P.; Rogers, R. D. *Organometallics* **1989**, *8*, 1915.
36. Shriver, D. F.; Drezdson, M. A., "The Manipulation of Air Sensitive Compound", Wiley: New York, 1986, p 38.
37. Sheldrick, G. M., SHELX 76, a system of computer programs for X-ray structure determination as locally modified, University of Cambridge, England, 1976.
38. Sheldrick, G. M., SHELXS *Acta Crystallogr.* **1990**, *A46*, 467.
39. "International Tables for X-Ray Crystallography"; Kynoch Press, Birmingham, England, 1974; Vol. IV, 1974, pp 72, 99, 149 (Present distributor: Kluwer Academic Publishers, Dordrecht and Boston.)

TECHNICAL REPORT DISTRIBUTION LIST - GENERAL

Office of Naval Research (1)*
Chemistry Division, ONR 331
800 North Quincy Street
Arlington, Virginia 22217-5660

Dr. Richard W. Drisko (1)
Naval Facilities & Engineering
Service Center
Code L52
Port Hueneme, CA 93043

Defense Technical Information
Center (2)
Building 5, Cameron Station
Alexandria, VA 22314

Dr. Eugene C. Fischer (1)
Code 2840
Naval Surface Warfare Center
Carderock Division Detachment
Annapolis, MD 21402-1198

Dr. James S. Murday (1)
Chemistry Division, Code 6100
Naval Research Laboratory
Washington, D.C. 20375-5320

Dr. Bernard E. Douda (1)
Crane Division
Naval Surface Warfare Center
Crane, Indiana 47522-5000

Dr. John Fischer, Director (1)
Chemistry Division, C0235
Naval Air Weapons Center
Weapons Division
China Lake, CA 93555-6001

Dr. Peter Seligman (1)
Naval Command, Control and
Ocean Surveillance Center
RDT&E Division
San Diego, CA 92152-5000

* Number of copies to forward